PHILIPS

TRANSISTOR CURVE-TRACER

PM 6507

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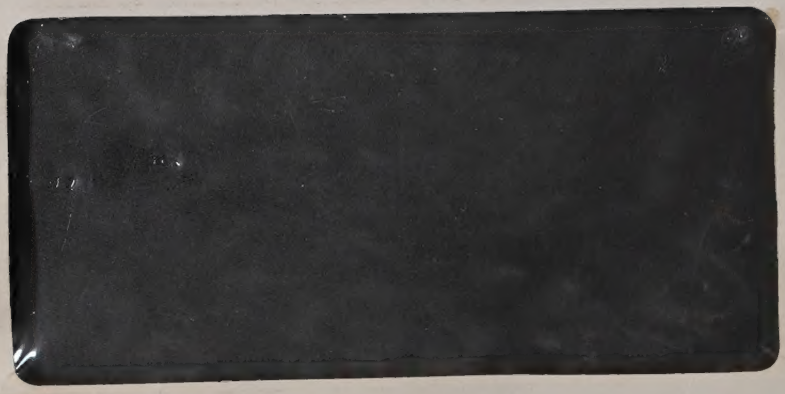

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PHILIPS

operating manual

TRANSISTOR CURVE-TRACER

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CS 9848

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IMPORTANT

In correspondance concerning this apparatus, please quote the type number and serial number as given on the plate at the back of the apparatus.

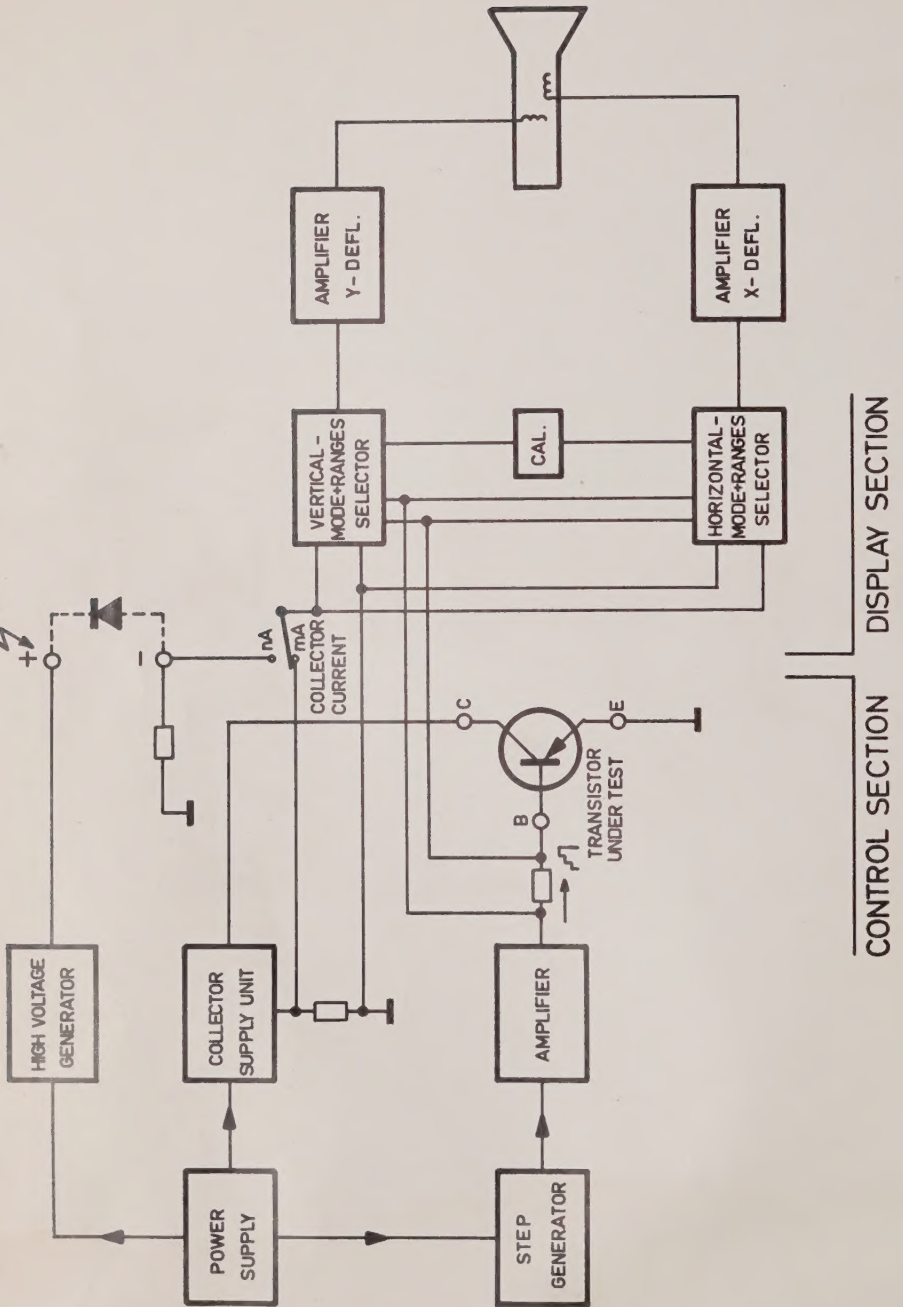

Fig. 1. Basic construction

GENERAL

I. INTRODUCTION

The PHILIPS Curve-tracer PM 6507 is a universal instrument for measuring and determining the characteristics of transistors and diodes. On the square flat c.r.t. it is possible to display single curves as well as sets of curves (up to 8) in various modes. The switchable duty-cycle control circuit permits of displaying characteristics oı power transistors up to their limits, without subjecting these transistors to thermal overload.

The current and voltage sources for supplying the semi-conductors under test have a very wide range (I_C max. 20 A, V_{CE} max. 500 V).

For testing the breakdown characteristics of diodes a separate H.T. source (max. 3000 V) is available.

Due to its special circuitry the curve tracer can satisfy the high standards set in semi-conductor measuring techniques.

It is therefore extremely suitable for being used in laboratories, but may also serve as a test apparatus for selecting and comparing semi-conductors with certain properties.

II. WORKING PRINCIPLE

The simplified diagram of Fig. 1 shows the basic construction of the PM 6507. From this diagram it appears that the apparatus essentially consists of 2 sections, namely:

- the supply and control section, and
- the display section with the c.r.t.

- The supply and control section comprises all control elements required for setting the desired mode of operation and adjusting the unit to the operating data of the semi-conductor under test. For testing a transistor these are the collector and base supply voltages.
  For the collector circuit a direct voltage source of maximum 500 V is available.
  This voltage has been divided into four ranges, which can be selected by means of push-buttons, and is continuously adjustable within these ranges.
  The base circuit is driven by the step generator.
  Dependent on the repetition frequency and the step value selected, a base signal is obtained which has the shape of a step curve. This will give rise to current and voltage variations in the collector circuit of the transistor under test which correspond to the properties of this transistor.
- The relevant data are applied to the display section and displayed on the c.r.t. It is possible to select a display method for the curve or set of curves which is in accordance with the operating mode of the transistor. The horizontal and vertical deflection amplifiers can be adjusted to optimum resolution over a wide range so that accurate and clear measurements can be made.
  For testing diodes in the breakdown region the apparatus has been provided with a separate HT generator which can supply voltages up to 3 kV.

III. BLOCK DIAGRAM

The block diagram (Fig. 2) gives a survey of the arrangement of the various circuits. In order to obtain a better understanding of the switching functions the relevant switches are shown in the appertaining units in a simplified form. This has only been done in order to explain the general principle and not to explain the individual units.

A mains transformer which can be adapted to 2 voltage ranges delivers the various voltages required for supplying the apparatus. The collector supply unit serves for supplying the collector circuit. The voltage ranges which can be pre-selected in 4 steps by means of push-buttons can be adjusted to any intermediate value by means of a variable transformer.

Selection of the polarity of the d.c. supply voltage is effected by means of push-button PNP-NPN. It is moreover possible to include 20 different resistors with values from 0...100 kΩ in the collector circuit; these resistors serve for current limiting and protect the semi-conductor under test against overload.

The above-mentioned variable transformer also serves to adjust the high tension for testing diodes in the breakdown region, whereby the voltage can be increased continuously up to 3 kV.

For measuring leakage currents seven μA and ten nA ranges are available.

1. Control section

a. Step generator

The step generator produces the step voltage for supplying the base circuit. From a winding of the mains transformer two trigger frequencies of 100 Hz which are shifted 90^{o} with respect to each other are taken and rectified. By means of slide switch "CURVES/sec" either or both frequencies are applied to the pulse shaper. This shaper delivers short needle pulses which drive the ring counter by means of which the step voltage is obtained, and moreover trigger a monostable multivibrator. The duty cycle of this multivibrator can be adjusted by means of control "Duty cycle". During the pulse cycle of the multivibrator the step voltage of each individual stage is applied to the differential amplifier. As soon as the multivibrator changes over, the step voltage is short-circuited so that interrupted steps are obtained. When control "Duty Cycle" is at 100 % the multivibrator is inoperative. The steps then appear without interruption.

Dependent on the selected pulse frequency and duty cycle either the beginning or end of the curve can be displayed or both the beginning and end. This method has the advantage that the semi-conductor under test is only loaded during the phase displayed so that it is possible to write the characteristics at the maximum power ratings without the risk of thermal overloading. The differential amplifier serves to accurately maintain the preset operating data of the base circuit and to correct these by means of reference values.

For this purpose the operating currents or voltages on the semi-conductor under test are applied to the differential amplifier via an impedance transformer, which via the power amplifier keeps the output amplitude at the nominal value.

The polarity of the step signal (and consequently of the collector voltage) can be preset by means of a push-button (PNP-NPN). Voltage V_{BE} only can also be preset for normal and inverse operation. Another push-button serves for selecting common emitter or common base arrangement.

For adjusting the exact zero point of the step curve datum line control "ZERO" is employed. By means of this control the lower curve (i.e. base current 0) is adjusted to the value of the leakage current. Thus a proper curve display is obtained which is based on the leakage current.

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The step current and voltage ranges are selected by switching in resistors. When the base circuit is supplied with a constant voltage series resistors of 0...10 MΩ can be included.
This additional resistance provides matching of the voltage generator and limits the current through the base-emitter circuit. Depending on the position of slide switch "TRANSISTOR INPUT" the input of the semi-conductor under test is driven (DRIVEN), grounded (GROUNDED) or open-circuited (OPEN).

b. Collector voltage supply

The collector voltage is adjusted by means of a continuously variable transformer. The two following transformers in push-pull arrangement have 4 voltage ranges, which can be selected by means of push-buttons. The control range then covers the relevant voltage range of the selected stage and the output voltage is full-wave rectified.
The pulsating d.c. voltage should not be smoothed in order to permit full deflection of the adjusted collector voltage from zero to maximum. The polarity of this voltage can be reversed by means of push-button switch PNP-NPN. Resistors of 0...100 kΩ can be included in the current circuit in steps for current limitation (LOAD).
The current as well as the voltage are determined in resistance dividers. In this way the measuring conditions are independent of each other for all ranges.

c. Connection of the semi-conductor under test

Two transistor holders (and socket connectors) TS1 and TS2 serve for connection of the semi-conductor under test. By means of the switch either TS1 or TS2 can be connected; in the centre position both transistors are disconnected.
Connection strip TS1 has been provided with coaxial double-sockets (Kelvin take-offs).

d. Additional supply sources

1. Diode voltage source

For testing semi-conductors or other 2-pole elements the apparatus has been provided with a half-wave H.T. voltage source. This voltage source is also continuously adjustable from 0 to 3 kV by means of the variable transformer. The voltage-current characteristic is displayed on the c.r.t., whereby 3 voltage measuring ranges are available, as well as several switchable ranges for μA and nA measurements.
Push-button "Read" connects the H.T. circuit only when it is closed manually or by means of a protection device.

2. Voltage source for fourth electrode

Connection socket "S" on the transistor holder, apart from earthing the transistor case (e.g. with H.F. transistors), may also serve for connecting e.g. a second gate in case of field effect transistors. For this a variable direct voltage of max. 10 V can be applied (Shield Voltage), whose polarity can be selected by means of a switch.

2. Display section

The display section of the curve tracer does not affect the working of the other sections. After having passed the relevant circuits and after being amplified the voltage or current changes occuring in the transistor are displayed on the c.r.t.
Two step-switches serve for range selection and mode selection for the horizontal and vertical deflection.

The horizontal deflection comprises 12 collector voltage ranges, 4 base voltage measuring ranges, one step range position, 3 ranges for diode test voltages and position "EXT" for external control.

By means of the step switch for the vertical deflection the collector current range is selected in 18 steps, whereby the sensitivity of 10 steps can be increased by a factor 10^3 for measuring diode leakage currents.

Moreover, the base voltage measuring sensitivity can be adjusted in 4 steps by means of this switch and an additional position is available for external control. By means of a slide switch all vertical deflecion ranges can be extended to either side by a factor 0.5 and 5.

To enable proper curve display in case of an inverted signal, a switch has been provided by means of which the polarity of the horizontal and vertical deflection voltages can be reversed.

This switch also serves for switching on the calibration voltage ("CAL").

The voltages present on the semi-conductor (or the current relations) are not influenced by the display section.

Therefore the operating voltages for the semi-conductor under test are applied to the differential amplifiers via high-ohmic input stages. The output amplifiers supply the power required for the magnetic deflection, whereby the trace can be shifted in the horizontal and the vertical direction by means of the combined coarse and fine controls.

The accelleration voltage for the picture tube is delivered by a 4.5 kV generator.

In order to keep the brightness of the picture constant at different sweep speeds a brightness modulator has been provided which increases the intensity at the higher speeds.

The brightness of the picture is also influenced by control "Duty Cycle".

IV. TECHNICAL DATA

Tolerances: Numerical values with statement of tolerances are guaranteed by the factory. Data without tolerances serve merely for information and represent the properties of an average apparatus.

Step generator

Step current generator:

Current steps (constant current values)	: 1, 2, 5 µA etc ... 200 mA/step (17 steps plus a 0 - step)
Number of curves	: 7 (18 with datum line) adjustable from 2...8
Stability of the step spacings	: Between the first and seventh step within an arbitrary range < 1 % with respect to each other; in all ranges < 3 %
Stability of the current generator	: A load variation of 10 % causes an error of < 1 % in all ranges

Step voltage generator:

Voltage steps mV/step	0	20	50	100	200	500	1000
max. internal resistance Ω: (current per step 200 mA)	0.1	0.1	0.25	0.5	1	2.5	5

Switchable source resistors : steps: 0, 1, 2, 5 ohm etc...10 MΩ (23 steps)

Duty cycle : at 100 pulses/sec. 250 µs...6 ms
(2.5 %...60 % and 100 %)
at 200 pulses/sec. the same pulse times apply, however, twice the duty cycle in percentages.
Overlap from 4 ms.

Zero adjustment of the step voltage : Can be shifted 100 % (7 steps) in the positive or negative direction
(at 200 mA/step and 1,000 mV/step max. 12 V at 30 % duty cycle)

Collector supply

Rectified sine-wave voltage, continuously adjustable in 4 ranges

Voltage range	Max. current	Internal resistance Ri (at 220 V)
0... 10 V_{ss}	20 A	0.3 Ω
0... 50 V_{ss}	4 A	3.8 Ω
0...100 V_{ss}	2 A	16 Ω
0...500 V_{ss}	0.2 A	400 Ω

Polarity : Reversible by means of button PNP-NPN

Overload protection : By means of thermo-magnetic switch.
Response time at 2x the nominal current: approx. 15 secs.
Response time at 10x nominal current: 0.05 secs. at max.

Current limitation : By means of switchable series resistors
Resistance scale:
0, 0.1, 0.2, 0.5 Ω etc...100 kΩ ± 10 % (20 steps)

Diode voltage source

Voltage range : (continuously adjustable half-wave voltage)
0...3000 V_{p-p}

Maximum load current : 1 mA

Short circuit current : 10 mA_{p-p} at max.

Internal resistance : 370 kΩ

Voltage source for 4th electrode : 0...10 V; continuously adjustable from 0 to + or -10 V
Connection to the "S" socket

Display section

C.r.t. : Type AW 17/69, flat screen 10 x 12 cm magnetic deflection, electrical focussing.
4.5 kV acceleration voltage

Beam current intensity : Externally adjustable, moreover automatic brightness modulation depending on duty cycle and sweep speed.

Lattice illumination : continuously adjustable

Y-deflection : Collector current: 10-20-50 µA/cm... 5 A/cm (18 steps)
Diode current : 10-20-50 nA/cm...10 µA/cm (10 steps)
Step function : 1 step/cm (step adjustment according to "step selector")
V_{BE} ranges : 20-50-100-200 mV/cm

Expansion switch : All deflection ranges can be extended by a factor .5 or 5.
External deflection coefficient: 10 mV/cm (5 mV or 50 mV/cm)
Polarity of the deflection: reversible
Shift range: 10 times the screen height

X-deflection : Collector voltage: 10-20-50 mV/cm...50 V/cm (12 steps)
Diode voltage : 100-200-500 V/cm
Step function : 1 step/cm (step adjustment according to "step selector")
V_{BE} ranges : 10-20-50-100 mV/cm
External deflection coefficient: 10 mV/cm
Deflection polarity: reversible
Shift range : 10 times screen width

External input : Symmetrical : 10 mV/cm
Input resistance*): 1,000 MΩ, at Y2/X1/X2 internally shunted with 1 MΩ
Drive voltage : max. 1 V_{p-p}
Maximum permissible input voltage: 100 V d.c. (short-term)
Maximum permissible common mode voltage: 8 V_{p-p}

External connection facility for : Z-modulation
Datum line adjustment
External step signal programming
Auxiliary voltage: ± 30 V

Calibration : Calibration voltage: 50 mV ± 0.5 % causing a deflection of 5 cm (horizontal and vertical)

Mains supply : 115 V and 230 V ± 15 %
Frequency: 40...60 Hz; also suited for 400 Hz

Power consumption : approx. 50 VA at normal load
approx. 250 VA at max. load

* The 1 MΩ shunt resistors (R362, R363, R426) can be removed.

Inaccuracy	: Measuring resistors < 1 % Indication: < 3 % for a field of 8x10 cm
Ambient temperature	: $+10^{o}...+35\ ^{o}C$ without any adverse effect $-10^{o}...+50\ ^{o}C$ additional error of $\pm$ 2 % $-20^{o}...+60\ ^{o}C$ operational at reduced power
Mechanical data	: Dimensions: Height 22 cm Width 45 cm Depth 32 cm Weight : 21 kg

V. ACCESSORIES

1 Mains cable
2 Transistor adapters PM 6549 (for L.F. and power transistors)
1 Manual

Optional accessories:

Transistor adapter	PM 6545 for power transistors (case SOT9; DIN 9A2)
Transistor adapter	PM 6547 (for RF transistors)
Transistor adapter	PM 6548 (empty case for mounting special holders)
Transistor adapter	PM 6549A (for power transistors with Kelvin take-offs)
Diode adapter	PM 6546
Camera flange	PM 9317 for camera PM 9300

DIRECTIONS FOR USE

VI. INSTALLATION

A. Adjustment to the local mains voltage

At the rear of the apparatus (Fig. 3) a voltage adapter has been fitted by means of which the apparatus can be adjusted to the local mains voltage. The apparatus can be adapted to 2 mains voltages, i.e. 115 V ± 15 % and 230 V ± 15 %.

Fuses VL1 and VL2: for 230 V: 1 A (delayed action type)
for 115 V: 2 A (delayed action type)

The 2A-fuses are situated in the two holders shown in fig. 3..

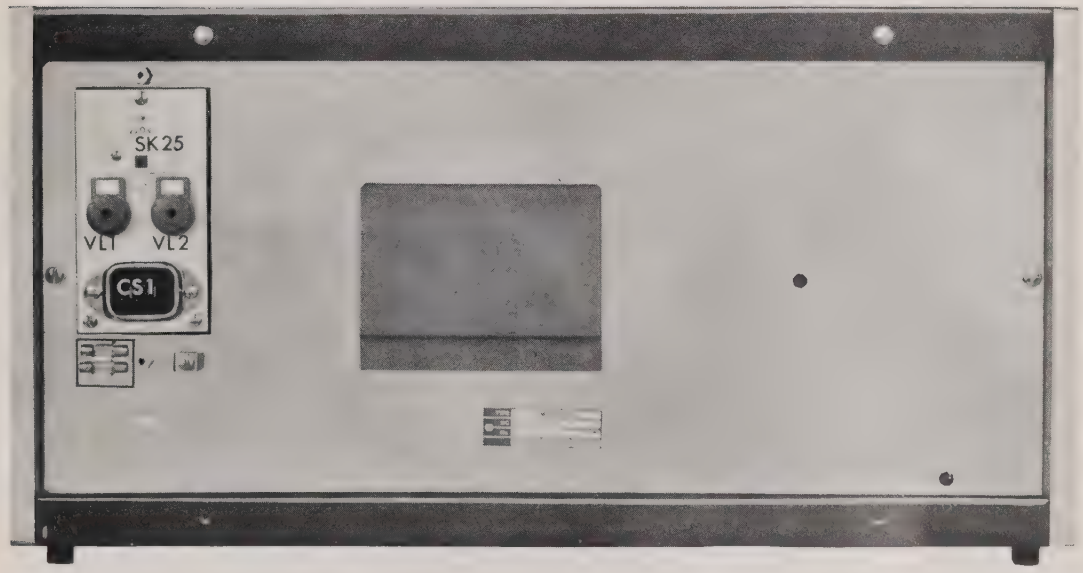


Fig. 3. Rear side of the instrument

B. Earthing

The apparatus should be earthed in accordance with the local safety regulations.

This may be effected:

- Via the accessory 3-core mains cable, provided that this is connected to a mains socket with rim earthing.
- Via earthing screw ⏚ at the rear of the apparatus.

C. Connection to the mains

- Before connecting the unit check that the voltage adapter is set to the correct position.
- Connect the apparatus to the mains (check earthing) and switch it on by means of mains switch "POWER ON".
- The pilot lamp above the switch should light up.

D. Rack-mounting version

The dimensions of the transistor curve tracer permit of mounting the instrument into a 19" rack. For this purpose a cornerpiece should be fitted on each side.
These pieces are already present in the instrument.
For converting the instrument proceed as follows:

- Remove the two side plates (4 screws each).
- Remove the 4 feet.
- The cornerpieces have been mounted on each side by means of 2 screws "A" (Fig. 4). Remove these screws, take out the cornerpieces and refit the screws.
- Remove the frontmost screws "B" and fit the cornerpieces by means of these screws.
- Refit the side plates.

When mounting the instrument ensure that the air circulation is not impeded. Especially make sure that the instrument is not placed close to an apparatus giving off much heat (observe max. ambient temperature!).

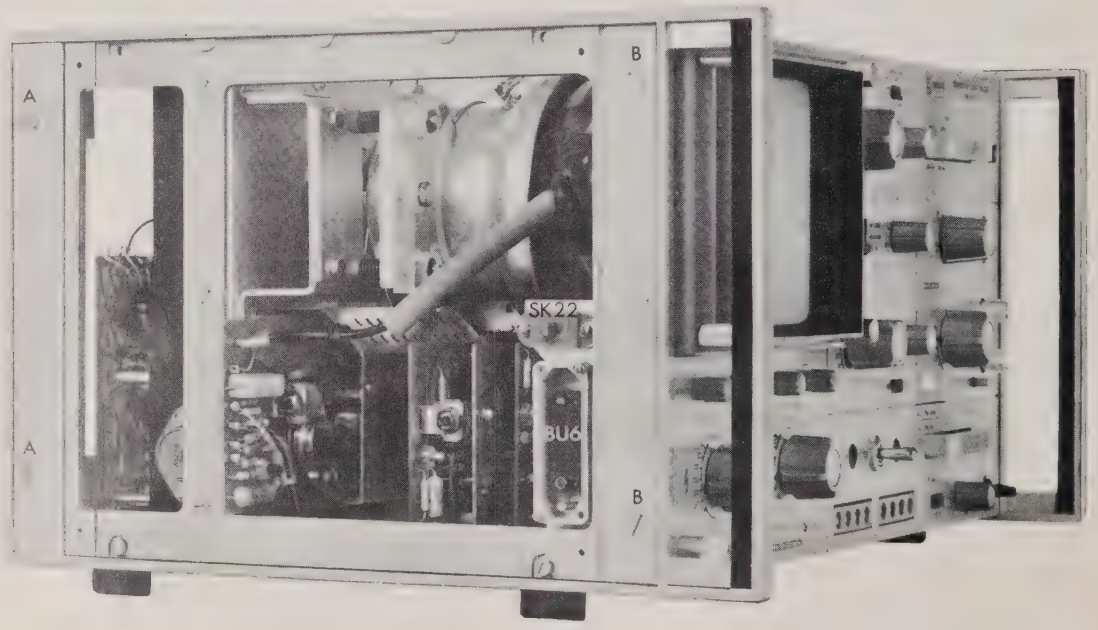


Fig. 4. Making the instrument suitable for a 19" rack

VII. OPERATING INSTRUCTIONS

A. Survey of the controls (Fig. 8)

B. Hints for testing semi-conductors

In practice it often appears that certain problems in measuring semi-conductors are due to misjudgement of the semi-conductor under test. In this chapter the most essential points are given which must be observed when testing a semi-conductor. First consideration: To which type belongs the semi-conductor to be tested?

Fig. 5.

Diode - Thyristor - PNP - or NPN transistor, Power, R.F. or L.F. transistor, Field effect transistor, etc.
Before connecting the transistor or diode to be tested it is necessary to establish type and power rating.

Second consideration: What points should be checked?

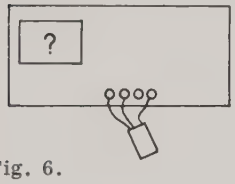


Fig. 6.

Short-circuit, leakage current, breakdown voltage, current gain, characteristics of a certain function etc.
The best method is to effect the measurement according to a definite testing procedure, especially with types whose characteristics are not known and which consequently may show deviations from the pre-set values.

Third consideration: Which is the max. power limit of the semi-conductor under test; which are the maximum permissible voltages and currents?

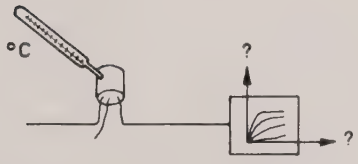


Fig. 7.

This point is very important, because especially in testing semi-conductors it may occur that the maximum permissible values are exceeded and the semi-conductor under test is damaged. In this respect, however, the curve tracer offers the possibility to display the characteristics at extreme values without overloading the semi-conductor.
The relevant instructions are given under point D 5.1.1-5.

C. Functions of the controls

The indications of the controls refer to Fig. 8.

SK1: CURVE/sec. 100 from 0 - 200 - 100 to 0.

This slide switch serves for adjusting the step frequency (100 or 200 Hz) and selection of the trigger point at 100 Hz.

For explaining the indications 100 from 0 and 100 to 0 the working of the step generator should be described a bit further.
For obtaining a step signal a voltage stepped from 0 to a certain maximum value is required at regular intervals.
From the maximum value the voltage drops again to 0 and the cycle is repeated. The step circuits are triggered by means of a 100 Hz~signal. There are two trigger points, one of which lies at the maximum value of the half-wave and the other one at the 0 point (Fig. 9).
These two trigger points determine the starting level of the step voltage whereby the pulse width can be adjusted from 2.5...60 % and 100 % by means of control "DUTY CYCLE".
This makes it possible to display either the first or the last part of a characteristic, or both when the curve tracer is set accordingly.
This facility has the advantage that the semi-conductor can be tested at low power dissipation when a display of the characteristics at the extreme values is required.

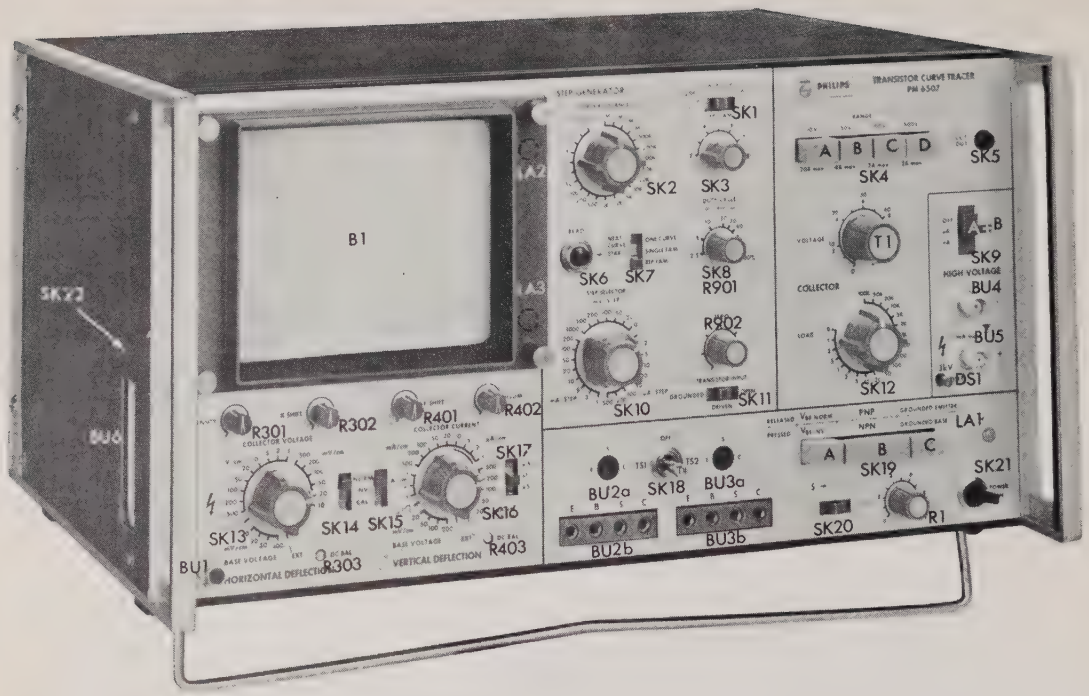


Fig. 8. Front view with controls and sockets

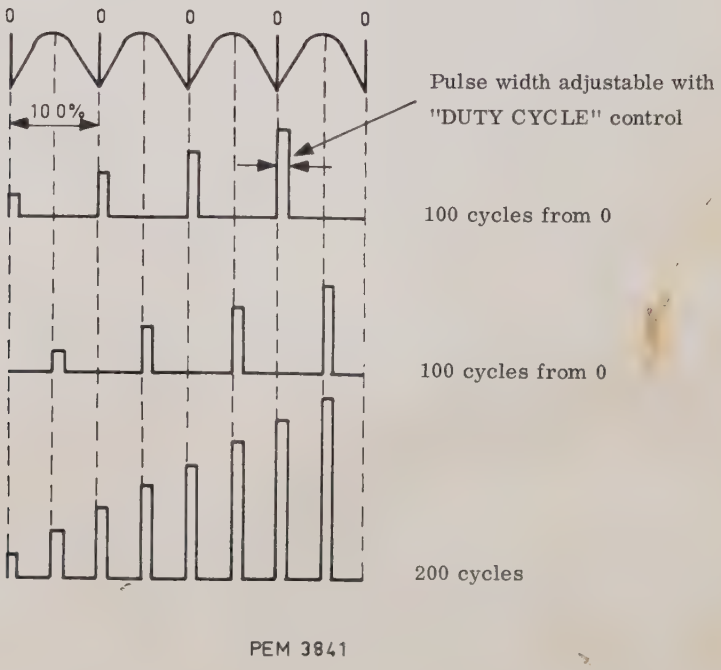


Fig. 9. Trigger point

SK2 SOURCE RESISTANCE Ω

It is possible to include a number of resistors from 0...10 MΩ in series with base circuit. These resistors serve for current limitation as well as for matching the base circuit.

SK3 This step switch serves for selection of the number of steps (or curves) to be displayed.

SK4 RANGE 10 V - 50 V - 100 V - 500 V

Push-button switch for selection of the collector voltage range.

SK5 CUT OUT

Excess-current cut-out for the collector voltage supply.
This thermo-magnetic switch cuts out at an excessive primary current.
Resetting is effected by depressing the red button.

SK6 READ

This push-button serves for starting a non-recurrent curve display or, in case of single curve display, for switching to the next step of the characteristic.

SK7 ONE CURVE - SINGLE FAM - REP. FAM

Slide switch for trigger-mode selection

ONE CURVE - Single curve
In this switch position only one curve is displayed whereby switching to the next step is effected by means of push-button "READ", dependent on the number of curves selected by means of SK3.

SINGLE FAM - One set of curves
In case of triggering by means of push-button "READ" non-recurrent display of the selected set of curves is obtained.
This display method is employed for heavily loaded transistors which do not permit of long-term operation or for photographic recording.

REP. FAM - Repeated display of the set of curves
In this switch position the selected curves are permanently displayed.

SK8 } DUTY CYCLE
R901 } This control serves for adjusting the duration of a curve, i.e. for adjusting the pulse width of the step signal (also see SK1).
The potentiometer permits adjustment of the pulse width between 2.5...60 % and in the fully clockwise switch position a duty cycle of 100 % is obtained.

SK9 HIGH VOLTAGE

Slide switch for switching on the H.T. generator for testing diodes as regards breakdown voltage. The switch also serves for selection of two measuring ranges, μA and nA.
These ranges correspond to the ranges of range selector SK16.

SK10 STEP SELECTOR

Range selector for adjusting the step values of the base-emitter circuit. The switch covers the three groups of ranges μA, mA and mV/step. The voltage or current step between two successive curves is determined by this switch. However, the selected value should be taken into account when establishing the value of the signal on the c.r.t., when SK13 or SK16 is in position ⌐¬.

SK11 TRANSISTOR INPUT

Slide switch for switching the input potential:

GROUNDED

In this position the input of the semi-conductor under test is connected to earth.

DRIVEN

In this position the input of the semi-conductor under test is driven by the step generator.

OPEN

In this position the input of the semi-conductor under test is open-circuited.

SK12 COLLECTOR LOAD Ω

Step switch by means of which resistors of 0...100 kΩ can be included in series with the collector circuit for current limiting and matching.
In this way the power dissipation of transistors operated near their load limits can be adapted individually which proves to be very useful in practice.

SK13 COLLECTOR VOLTAGE - BASE VOLTAGE

Range selector for horizontal deflection of the trace. The values indicated apply to 1 cm screen distance, independent of the step value selected with SK10, except for position ⌐⌐.
In latter position the step value of SK10 applies to 1 cm screen distance.
Position "EXT." serves for external horizontal deflection. Connection is effected via BU6 (sensitivity 10 mV/cm).

SK14 NORMAL - INVERSE - CALIBRATION

SK15 These slide switches serve for polarity reversal of the horizontal (SK14) or vertical deflection (SK15). This enables reversal of the trace in both directions, independent of each other.
Switch position "CAL" serves for checking the display circuit; a direct voltage of 50 mV is then applied to the amplifier inputs.
The indications near range selectors SK13 and SK16 remain valid (with the exception of switch position ⌐⌐ as well as the base voltage ranges 10...100 and 20...200). The trace on the screen will be 5 cm. For the ranges in brackets the range values selected should be observed, and in position ⌐⌐ the sensitivity is 100 mV/cm i.e. a shift of 0.5 cm.

SK16 COLLECTOR CURRENT - BASE VOLTAGE

Range selector for vertical deflection of the trace.
The range values apply to 1 cm screen distance, independent of the step value chosen with SK10, except for switch position ⌐⌐ . In this position the step value of SK10 holds good for 1 cm screen distance. Position "EXT" serves for external vertical deflection. Connection is effected via BU6 (sensitivity 10 mV/cm).

SK17 x.5 x 1 x 5

Expansion switch. By means of this switch the vertical deflection range (SK16) can be extended by a factor 2 in downward direction and by a factor 5 in the upward direction.

SK18 Toggle switch TS1 - OFF - TS2 for connecting semi-conductor TS1 or TS2.
The connection sockets for 4 mm plugs together with the transistor receptacles above these sockets are parallel connected via RF coils.
When the toggle switch is in the left-hand position the left hand receptacles and sockets are connected (TS1) and in the right-hand position TS2 is connected. In the centre position the sockets and receptacles are disconnected.

SK19 Push-button switch for PNP-NPN selection, changing over the V_{BE} from normal to inverse (polarity reversal of the B-E junction) and changing over from common-emitter to common-base arrangement.

SK20 Slide switch for selecting the + or -10 V direct voltage (⏚) which may be added to the "S" connection (shield). This voltage is for instance required for transistors with two inputs.

SK21 POWER ON
Mains switch for switching on the apparatus.

SK22 Slide switch for the use of the step-generator with external programming.
(Accessible via an apperture in the left-hand cabinet plate.)

SK25 Mains voltage adapter 115 V/230 V $\pm$ 15 % (at the rear of the apparatus).

T1 VOLTAGE
Variable transformer for adjusting the collector voltage and the high tension (when SK9 is switched on).

R1 Potentiometer for adjusting the "SHIELD" voltage from 0 to + or -10 V (dependent on the position of SK20).

R301 INTENSITY
Potentiometer for brightness control.

R302 X-SHIFT
Ganged potentiometer (coarse and fine adjustment) for horizontal shift of the trace.

R303 Potentiometer for adjusting the d.c. balance of the X amplifier.

R401 Y-SHIFT
Ganged potentiometer (coarse and fine adjustment) for vertical shift of the trace.

R402 SCALE ILLUMINATION
Potentiometer for adjusting the lattice illumination.

R403 Potentiometer for adjusting the d.c. balance of the Y amplifier.

R902 ZERO
Control for zero shift of the step signal.
The lower curve is adjusted to datum or leakage current level by means of R902.
For this adjustment SK11 is set at "OPEN", the datum line is read and after SK11 has been reset to "DRIVEN" the lower curve is adjusted to the reading obtained, by means of R902.
The datum line is correctly adjusted if the curve does not shift when SK11 is switched from "DRIVEN" to "OPEN".

BU1 Earthing socket

BU2a Transistor receptacle for small types } Switch position TS1
BU2b Connection sockets for power transistors } Parallel connections
The E-B and C-S connections have been provided with Kelvin take-offs (voltage and current fed-out separately to prevent measuring errors)

BU3a Transistor receptacle for small types } Switch position TS2
BU3b Connection sockets for power transistors } Parallel connections

BU4 } BNC sockets for connection of a protective holder or connection cable for testing
BU5 } diodes in the breakdown region (max. 3 kV).
(BU4 = measuring input)
(BU5 = high voltage output ⚡)

BU6 Multiple connector for external control (on the left hand side of the apparatus)

D1 Push-button to connect the high voltage to socket BU5.

LA1 On/off pilot lamp

LA2 }
LA3 } Lamps for lattice illumination

CS1 Mains socket with rim-earthing contacts (at the rear of the apparatus).

D. Operation

1. Basic setting

The basic setting of the apparatus depends on the type of semi-conductor and its characteristics as well as on the selected mode.
E.g., for measuring an NPN transistor of relatively low power the setting shown in Fig. 17 may be used. It is advisable to start with a low setting in case of a semi-conductor whose characteristic values are not exactly known. This setting can then be changed if a more accurate measurement is permissible.

2. Switching on the apparatus

After the controls have been set to the initial position, the apparatus can be switched on with switch "POWER ON". If the transistor is already connected it should be ensured that toggle switch SK18 is in the mid position; in this position the semi-conductors (TS1 and TS2) under test are disconnected.
The heating up time of the curve tracer is approximately 1 minute. After this the apparatus is ready for operation.

3. Connection of a semi-conductor

For connection of small transistors two receptacles are available and two socket connectors for 4 mm plugs.
The socket connector and the receptacles above it are parallel connected via R.F. chokes. These chokes prevent or suppress parasitic oscillation of R.F. transistors which for the same reason should be connected to the plug connectors.
In the left-hand position of the toggle switch the left-hand receptacles and sockets (TS1) are connected and in the right-hand position the right-hand sockets and receptacles (TS2).

4. Adjusting the display section

The display section should be adjusted to the correct horizontal and vertical sensitivity before the semi-conductor under test is connected. First adjust the spot on the screen by means of the X and Y shift controls.

The horizontal deflection corresponds to the collector-emitter voltage. As soon as a voltage is applied a horizontal line is displayed on the screen whose length is a measure of the sensitivity adjusted with SK13 or the collector voltage.

The vertical deflection defines the value of the collector current of the transistor.
Before the semi-conductor is connected range selector SK16 should be set to a sensitivity corresponding to the collector current to be expected.
As soon as a transistor is connected the current will flow through the collector circuit which depends on the selected base current or voltage. This current causes a deflection in the vertical direction on the screen, whereby the distance from the datum line to any point of the curve represents the value of the collector current.
The switches NORM./INVERT serve for reversing the trace in the horizontal and vertical direction. An expansion switch permits of extending the vertical measuring range by a factor 2 in the upward direction or by a factor 5 in downward direction.
Control INTENSITY serves for adjusting the intensity of the electron beam. To prevent damaging of the picture tube the beam current intensity should not be excessive, but should be adjusted so that a clear picture is obtained.

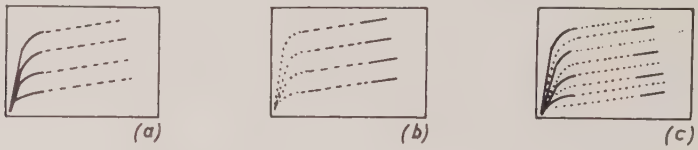
5. Setting for testing semi-conductors with 3 or 4 terminals

The following description gives a survey of the most important adjustments for displaying a characteristic. The example chosen applies to the display of I_C as a function of V_{CE}, with I_B as parameter, for an PNP transistor in a T0 5 case.

- Set all the controls to the position shown in Fig. 17 (toggle switch TS1 - OFF - TS2 in the centre position).
- Switch on the apparatus (switch POWER ON).
- Insert the transistor in the receptacle, e.g. BU2a.
- Check and preset:
  - V_{CE} - VOLTAGE
  - COLLECTOR LOAD
  - STEP SELECTOR μA, mA/STEP
  - HORIZONTAL DEFLECTION (range)
  - VERTICAL DEFLECTION (range)
- Set the toggle switch at TS1.
- Adjust for desired step current (or step voltage and series resistance SK2 for certain traces), and collector voltage.
- Adjust the horizontal and vertical deflection until proper curve display is obtained.
- Adjust step switch "LOAD Ω" so that the curve display is limited (e.g., according to the dotted line in Fig. 11).
- Adjust the level of the lower curve to zero with control "ZERO" by setting slide switch SK11 at "OPEN" and reading the zero line (given by the leakage current of the transistor).
  Reset the slide switch at "DRIVEN" and adjust the lower curve to the zero value found by means of control "ZERO".

- By means of control "DUTY CYCLE" the driving time of the step current can be reduced, so that only the beginning of the curve is visible when switch CURVES/sec. is at position "100 from 0", (Fig. 10a). In position "100 to 0" the second part of the curve trace is visible (Fig. 10b) and in position 200 the beginning and end of curve can be displayed, (see Fig. 10c and description under point 5.1.2).

Fig. 10.



5.1. Displaying curves with power limiting

The characteristics of semi-conductors at high loads can only be displayed when the semi-conductor cannot be damaged by this high load. For this purpose the curve tracer offers the following possibilities:

5.1.1. Curve display with limited duty cycle of the step current (DUTY CYCLE) 100 from 0
100 to 0

When a curve trace of a transistor is displayed the highest power dissipation occurs during the transition from the conductive to the non-conductive state. Fig. 11 shows a curve trace whereby the power dissipation limit P_C max. of .... mV is represented by the dotted line. This display method with limiting at P_C max. can be approximated with the curve tracer.

This is obtained by reducing the duty cycle of the step current (DUTY CYCLE) and by current limitation with series resistors included by means of the step switch (LOAD Ω). By means of the DUTY CYCLE control adjustment of the step width between 2.5...60 % and 100 % is possible (see Fig. 10 and the description under point C1).

These two methods enable reducing of the load of the semi-conductor under test to a minimum by displaying only that part of the characteristic which is of interest. The semi-conductor may then be loaded to high values without the risk of being overloaded.

5.1.2. Curve display with limited duty cycle of the step current, 200 Hz.

When the number of steps is even the curves are shifted to the beginning or end. In case of an odd number all curves are uninterrupted but, dependent on the duty cycle adjustment, the centre parts are driven to zero and become consequently interrupted or overlap.

In this way a survey of the entire characteristic is obtained at a limited load.

5.1.3. Curve display with current limiting by means of series resistors in the collector circuit.

Dependent on the base drive of a transistor currents will flow through the collector circuit which are a factor h_{fe} higher. When series resistors are included in the collector circuit a voltage drop will arise across this resistance which causes a decrease of the collector-emitter voltage of the semi-conductor under test which depends on the transistor drive. In this way a power limitation is obtained which can be adapted to the maximum permissible value of the transistor and which can be adjusted to any value within the resistance and voltage ranges (Fig. 11).

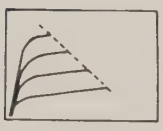


Fig. 11.

5.1.4. Non-recurrent curve display

If certain transistor settings do not permit of continuous operation, display in the "single" mode is possible.

For this slide switch SK7 is set at "SINGLE FAM".

Triggering is effected by means of push-button "READ" (SK6).

5.1.5. Curve display of one curve out of the set of curves.

From a set of curves, the number of which can be selected by means of switch STEP/FAM, each curve can be displayed individually. Switching over to a higher step is effected by means of push-button "READ" (SK6).

5.2. Displaying curves with voltage drive

5.2.1. Transistors

a. Leakage current measurements I_{CEX}, I_{CEO}, I_{CER}, I_{CES} and breakdown voltage BV. (Fig. 12)

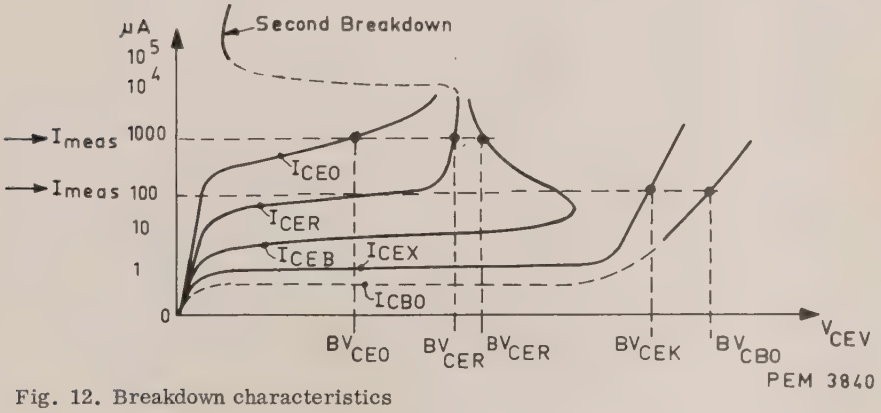


Fig. 12. Breakdown characteristics

Leakage current measurements I_{CER}, as well as breakdown voltage measurements BV_{CER} can be effected by means of the resistors from 0 Ω (CES) to 10 MΩ (CER) which can be switched by means of SK2 (SK10 in position 0 mV/Step). Open base measurements ($R_{BE} = \infty$/CEO) can be effected with SK11 (INPUT OPEN).

Measurements with voltage and resistance (CEX) can be effected as described above, however, SK10 should be adjusted to voltage (... mV/Step) and the polarity (SK19 A V_{DE} INVERS) should be reversed. By means of control R902 "ZERO" any voltage value can be selected.

During this measurement it should be observed that the power dissipation near the breakdown limits can be very high, so that it is recommended to limit the power dissipation by including resistors in the collector circuit.

b. Setting at small base currents:

Transistors with a high current gain can be measured most efficiently at a small I_C when the voltage drive on the base takes place via a high load resistance.

Example: 100 mV/step - 1 MΩ $\longrightarrow I_B = \frac{100\ mV}{1\ M\Omega} = 100$ nA/step

Compensation of the voltage in the non-linear part of the base-emitter diode characteristic is then possible by means of control R902 (Zero); see Fig. 13.

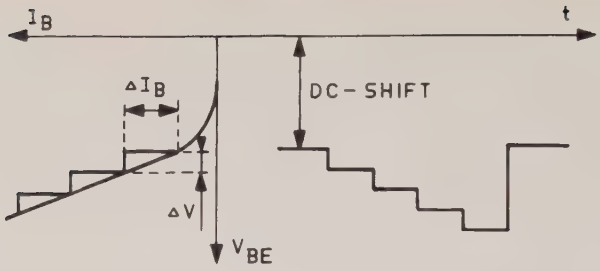


Fig. 13. Compensating for the non-linear part of the base-emitter diode characteristic

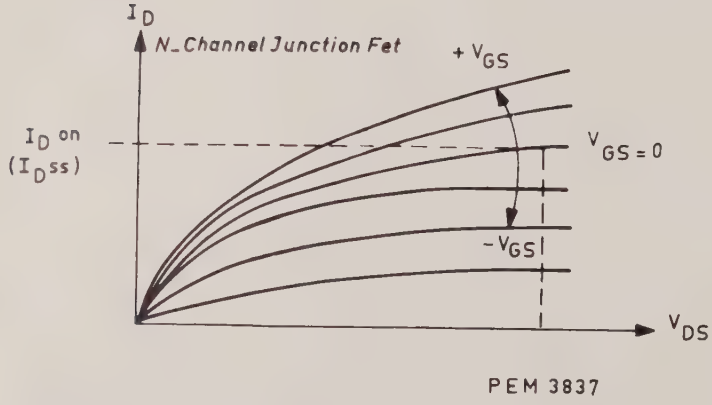


Fig. 14. I_D-V_{DS}-characteristic of an N-channel junction FET

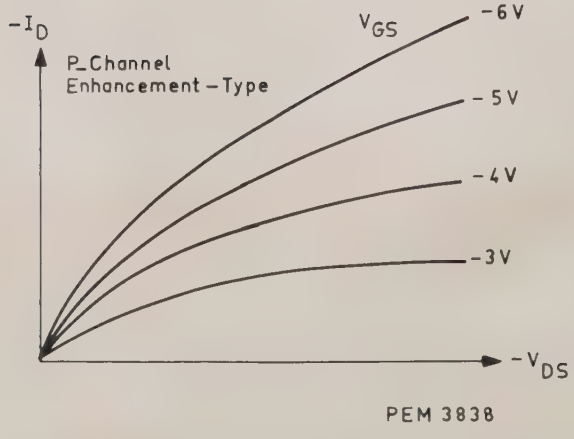


Fig. 15. I_D-V_{DS}-characteristic of a P-channel enhancement-type MOS-FET

5.2.2. Voltage driven elements such as FET:

a. Junction FET (also see 5.3)

Depletion - type MOS - FET

With these semi-conductors there is already a drain current (I_{DON}, I_{DSS}) at a gate-source voltage of zero volts. When the gate is driven by the step voltage this current varies.

The curves can then be changed by selection of the polarity and the internal resistance (Fig. 14).

b. Enhancement - type MOS - FET

In this type of transistor normally no drain current will flow without gate source voltage (Fig. 15).

As soon as a sufficiently high gate-source voltage is applied the drain current starts flowing (gate-source cut-off voltage).

5.3. Additional drive on a 4th connection (e.g. 2nd gate)

With the aid of control R1 and switch SK20 the 4th electrode can be employed for driving, so that special measurements are possible.

6. Setting for breakdown tests of diodes and other elements with 2 connections.

Because of the high voltages and high sensitivity the outputs and inputs have been isolated.

The voltage is adjusted by means of variable transformer T1 and switch SK9 enables a division into two current ranges.

For safety reasons the test voltage is cut out as soon as button DS1 is released.

A second safety contact is available when adapter PM 6546 which is supplied separately, is employed for testing diodes.

The voltage is then switched on only, if the cover is fitted and push-button D1 on the instrument is depressed.

7. Setting the instrument for external control or programming:

a. Application as X-Y oscilloscope

Connector BU6 on the left-hand side of the instrument can be employed for X-Y display.

The inputs are arranged as follows: ⏚ Socket H/K
X1 Socket D
X2 Socket F
Y1 Socket B
Y2 Socket E

b. Special measurements:

- Circuit for testing tunnel diodes
- Circuit for simultaneous display of two characteristics.

c. External programming of the step generator and external measuring circuits:

Automatic operation can be obtained by means of an external adapter. Independent of its normal application and the application as an X-Y oscilloscope the instrument can also be used as an automatic curve tracer.

The external programming unit is connected to connector BU6 on the left-hand side of the instrument. The basic arrangement for external programming appears from circuit diagram Fig. 16.

The auxiliary unit should be proportioned so that it agrees with the application and type of semi-conductor under test.

The following formulas serve for calculating the desired operating values in the step voltage generator and the collector supply.

Selecting reference resistor R_X in the step generator.

This resistor determines the step current per stage.

For $I \geq 500\ \mu A$/step $\quad R_X = \frac{100}{1\ (\text{in A/step})} - 1$

For $I \leq 500\ \mu A$/step $\quad R_X = \frac{100}{1\ (\mu A)} - 1$

Collector voltage:

This voltage should be preselected so that it corresponds to the max. test voltage. Lower voltages can be obtained by means of an external voltage divider (R_C), the series resistors simultaneously ensuring current limitation.

The horizontal deflection sensitivity of the monitor is determined by the two measuring voltage dividers A and B. These dividers can be made identical to the internal divider (R346-R357 and R332-R334), whereby the intermediate stages which are not required may be left out.

Collector current:

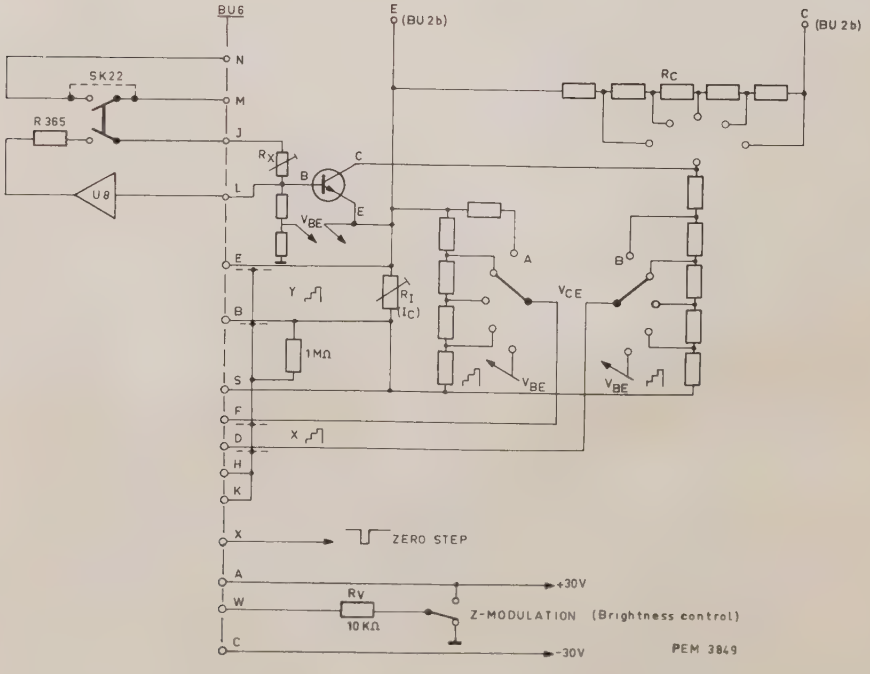
Measuring resistance R_1 is defined as follows:

$$R_1\ (\Omega) = \frac{10\ \text{mV/cm}}{1\ \text{mA/cm}} \leq 10\ \text{k}\Omega$$

(1 mA has been chosen as an example)

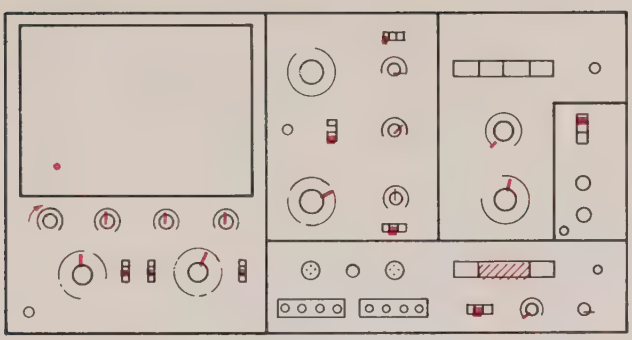
Base voltage:

For curve display as a function of the base-emitter voltage the X input should be connected to the base-emitter junction of the semi-conductor under test. The voltage divider to be employed should then be high-ohmic, so that the shunt of the base-emitter junction is small.



CS 9873

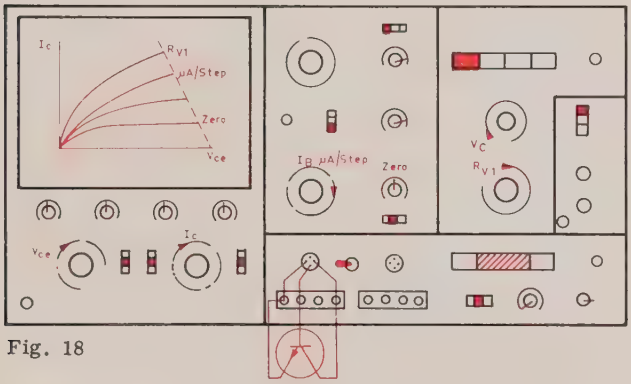
Fig. 16. Circuit for external programming



Basic setting
Adjust spot

NPN-TRANSISTOR

Fig. 17



Charact. $I_C = f(V_{CE})$
I_B = Parameter

NPN-TRANSISTOR

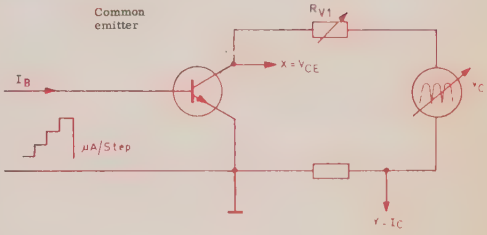
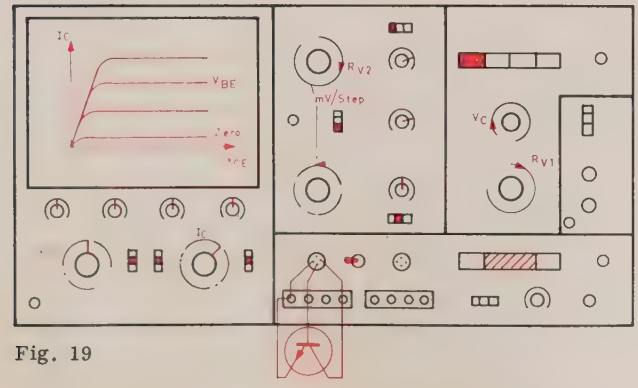


Fig. 18



Charact. $I_C = f(V_{CE})$
V_{BE} = Parameter

NPN-TRANSISTOR

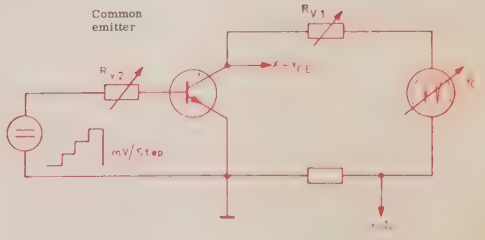


Fig. 19

Charact. $I_C = f(I_B)$

NPN-TRANSISTOR

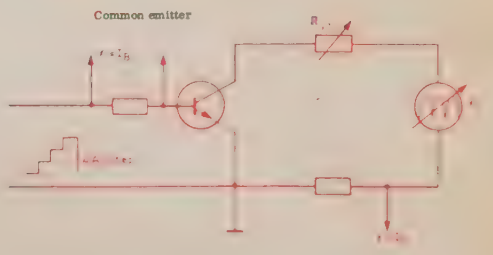


Fig. 20

CS 9874 Fig. 17 ... 43. Various measurements with the curve-tracer

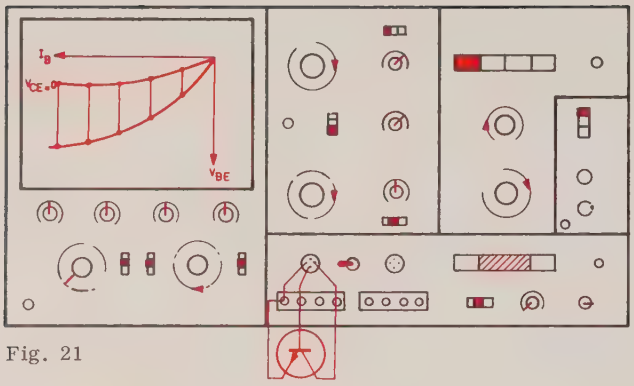
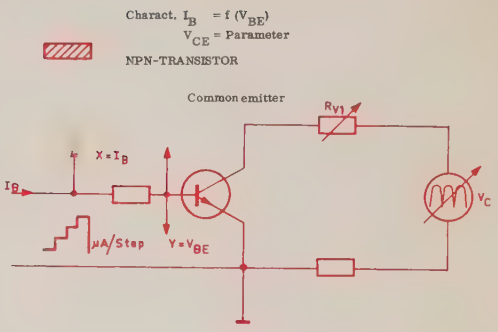


Fig. 21



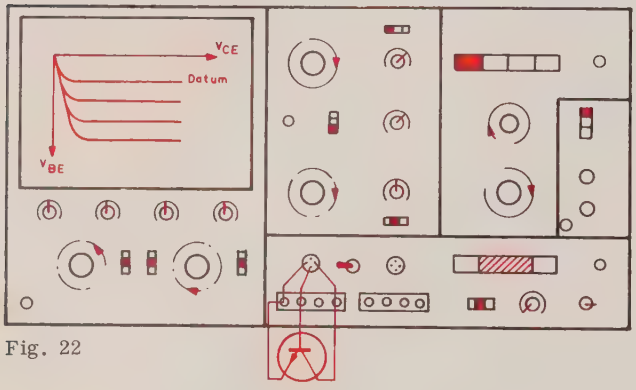
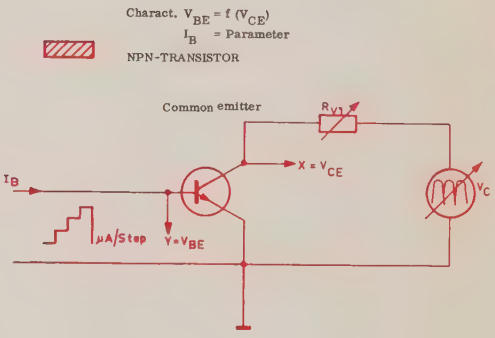


Fig. 22



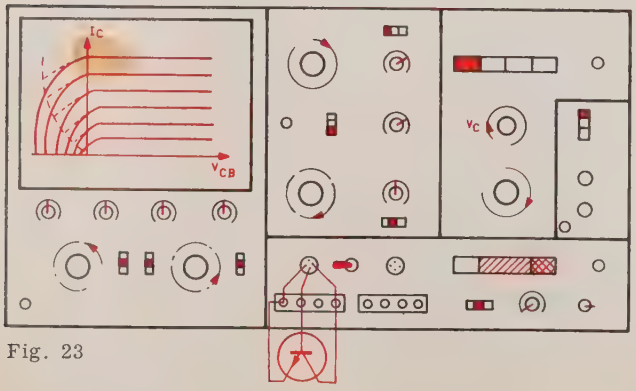
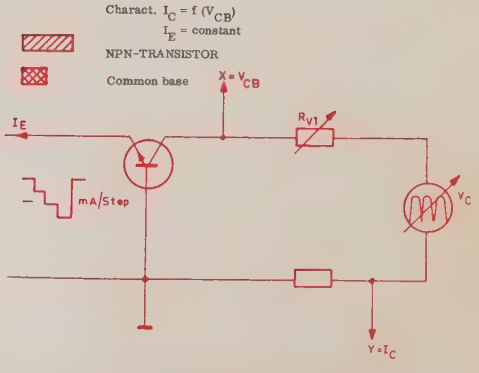


Fig. 23



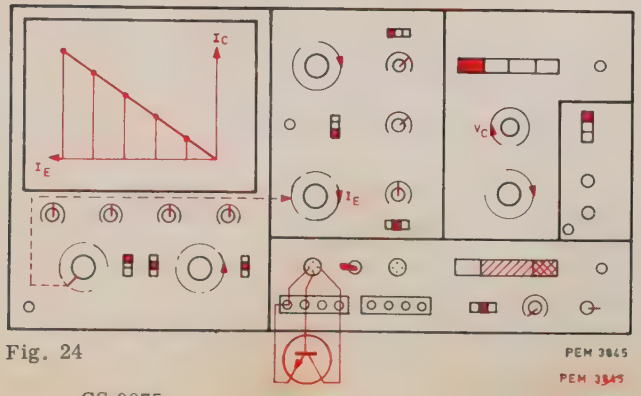
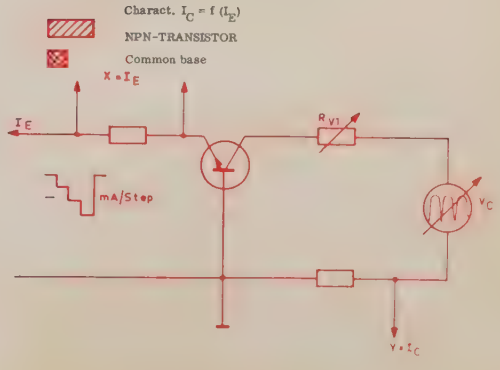


Fig. 24

PEM 3845

PEM 3845



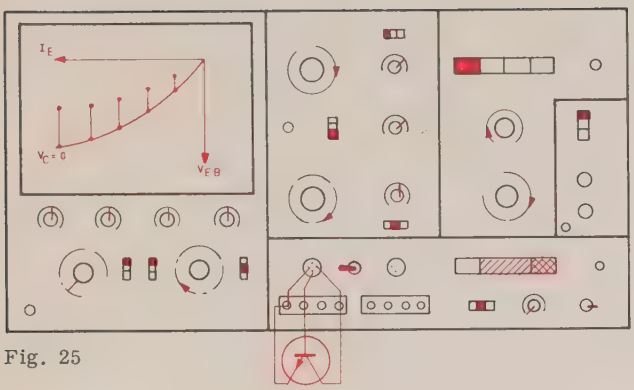
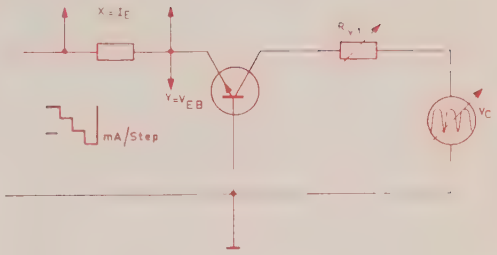


Fig. 25

Charact. $I_E = f(V_{EB})$

NPN-TRANSISTOR

Common base



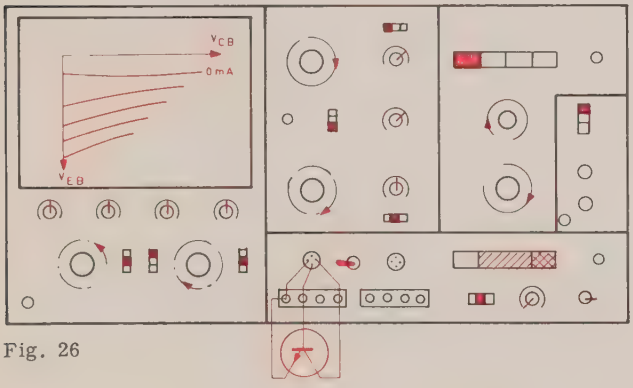
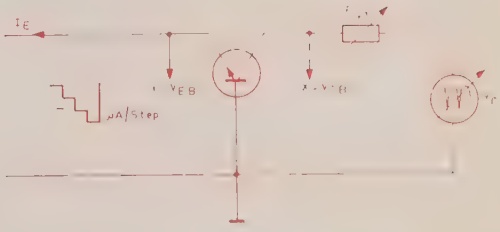


Fig. 26

Charact. $V_{EB} = f(V_{CB})$
I_E = constant

NPN-TRANSISTOR

Common base



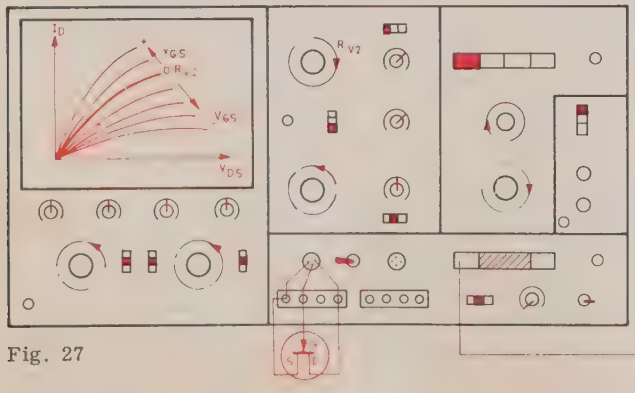


Fig. 27

Charact. $I_D = f(V_{DS})$
V_{GS} = constant

N CHANNEL FET

+ V_{GS} (NORMAL)

- V_{GS} (INVERS)

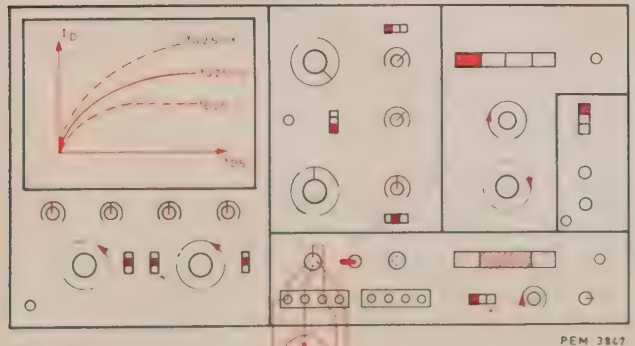
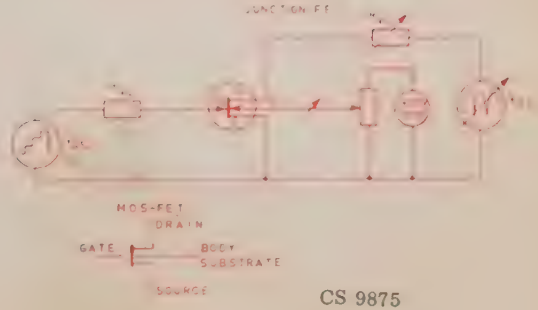


Fig. 28

Charact. $I_D = f(V_{DS})$
V_{G1S} = constant
V_{G2S} = Parameter

N CHANNEL FET with 2 gates



CS 9875

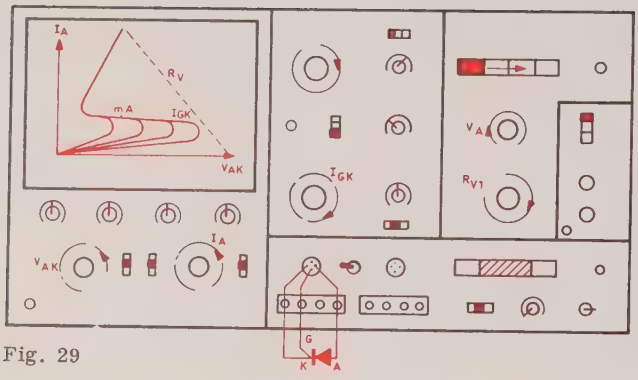
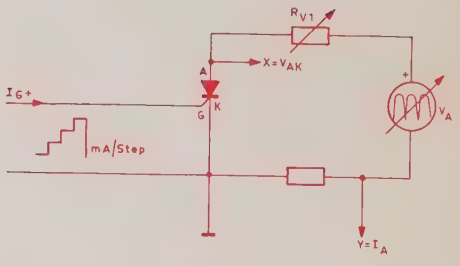


Fig. 29

Silicon controlled rectifier
THYRISTOR (SCR)



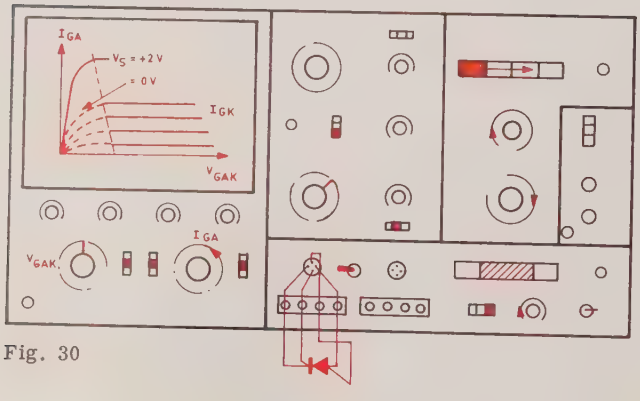
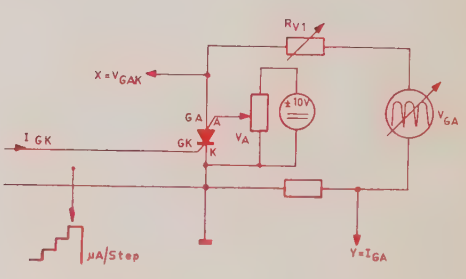


Fig. 30

Silicon controlled switch
(SCS)



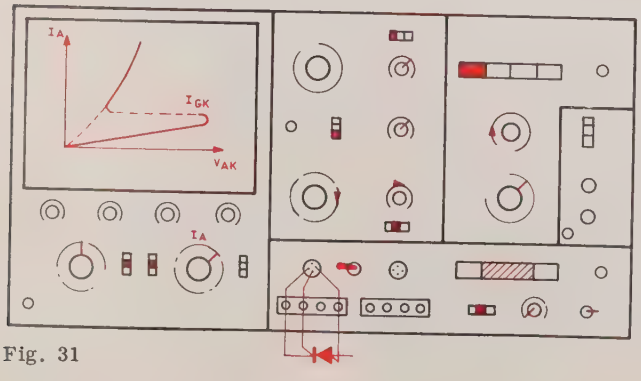
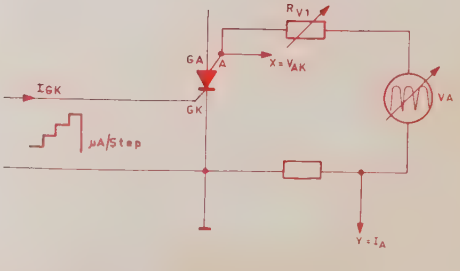


Fig. 31

(SCS)



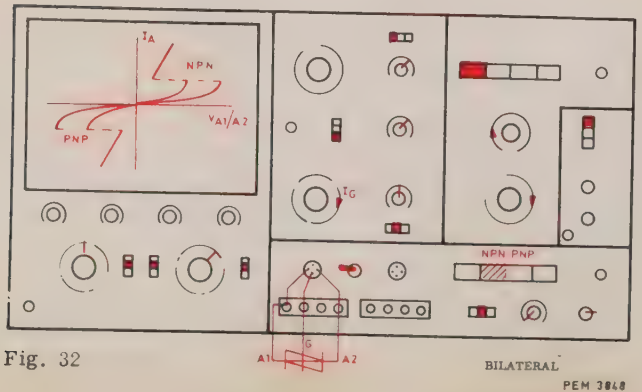
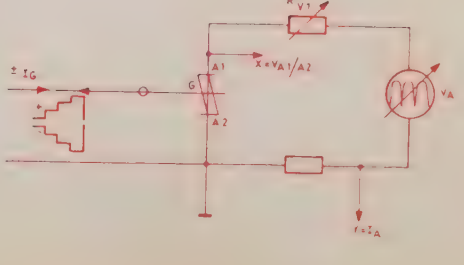


Fig. 32

UNILATERAL SWITCH
BILATERAL SWITCH



BILATERAL

PEM 3848

CS 9876

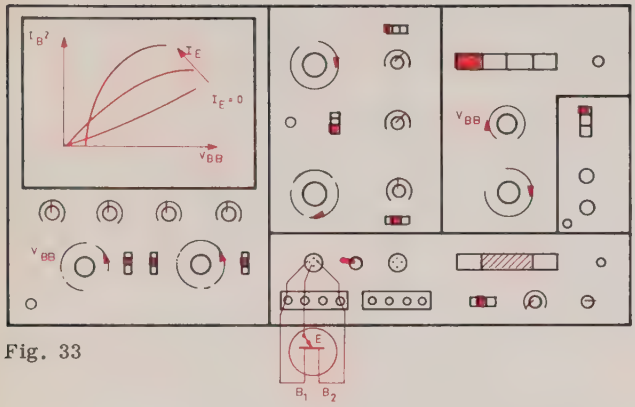
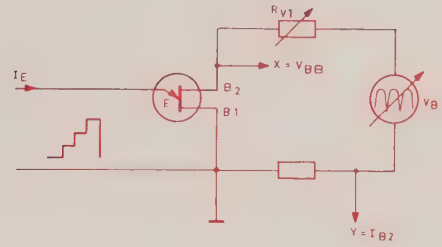


Fig. 33

UNIJUNCTION-TRANSISTOR
(UJT)



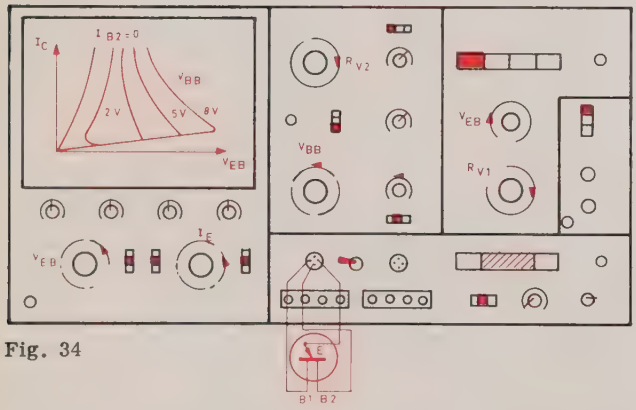
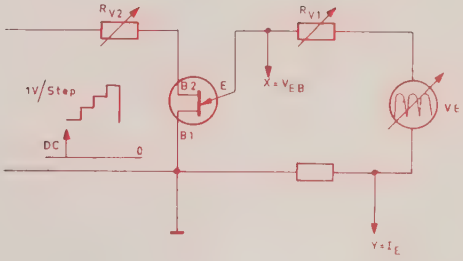


Fig. 34

UNIJUNCTION-TRANSISTOR
(UJT)



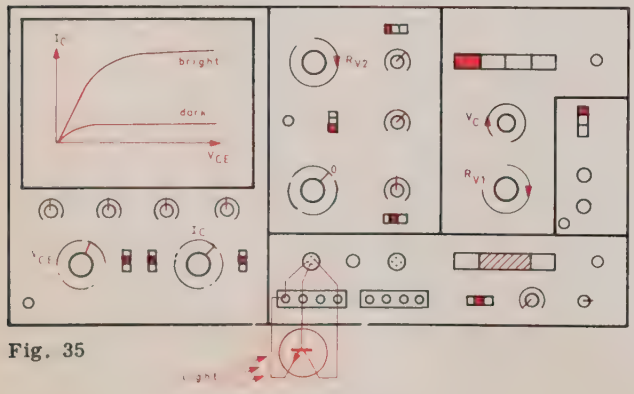
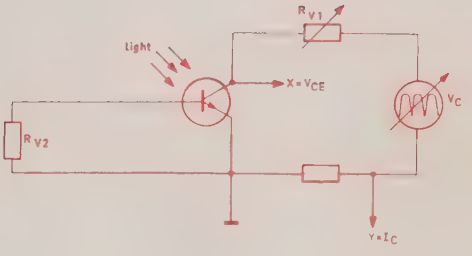


Fig. 35

FOTO-TRANSISTOR
NPN



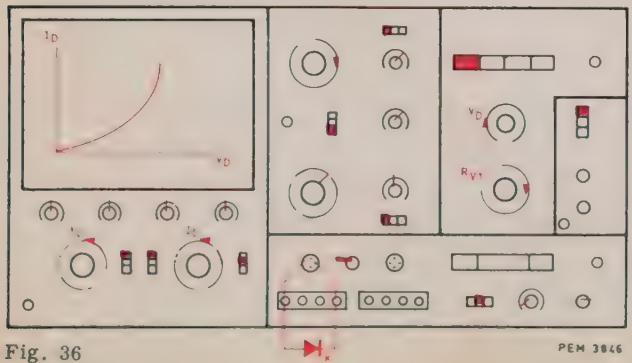
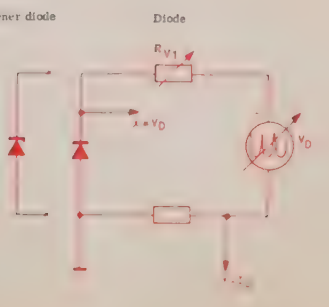


Fig. 36

PEM 3846

Forward direction



CS 9877

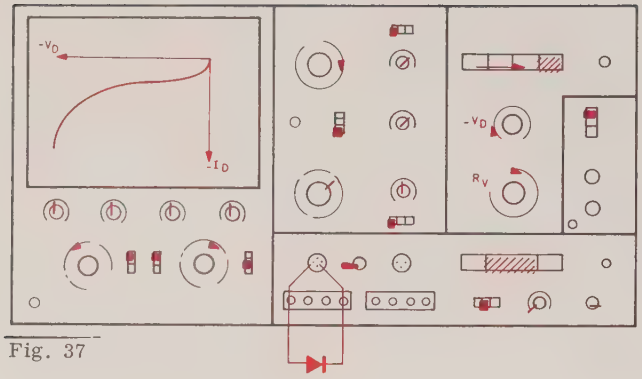


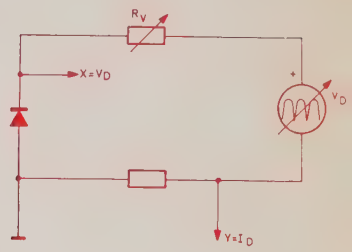
Fig. 37

Leakage current measurement, breakdown

DIODE reverse direction

NPN

to 500 V



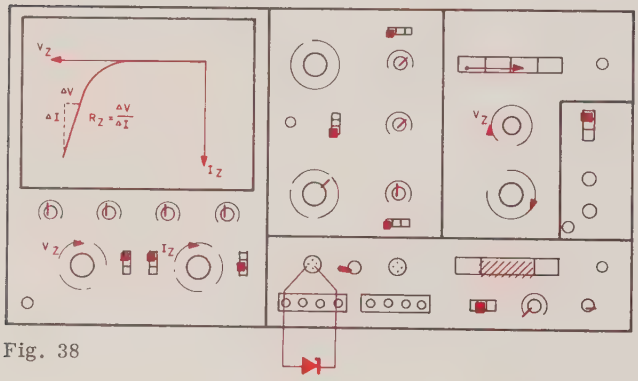


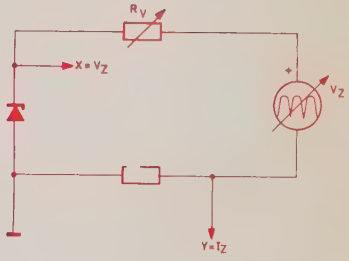
Fig. 38

Zener diode

Zener range

NPN

Expansion and shift 10x screen



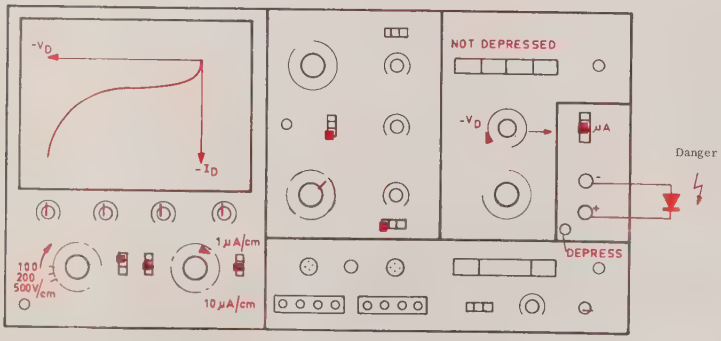
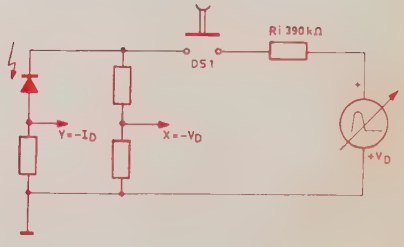


Fig. 39

Diode breakdown voltage

Measuring range 10 µA - 1 mA



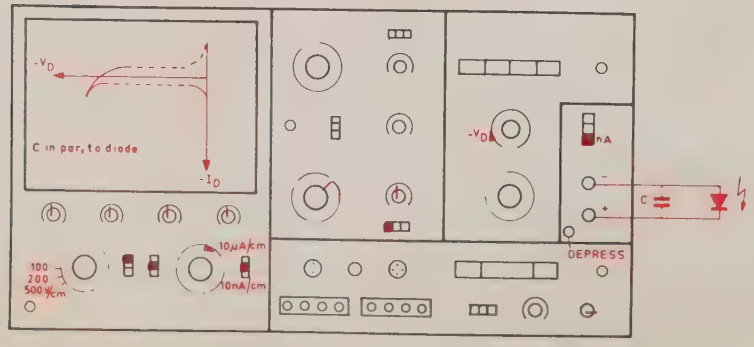


Fig. 40

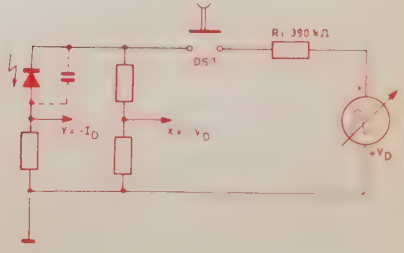
PEM 3844 With adapter PM 6546 no influence of C

PEM 3844

Diode breakdown voltage

Measuring range 10 nA - 10 µA

Pay attention to screening to avoid stray capacitance C



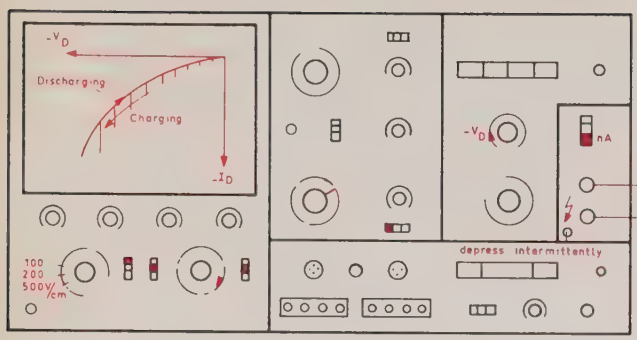
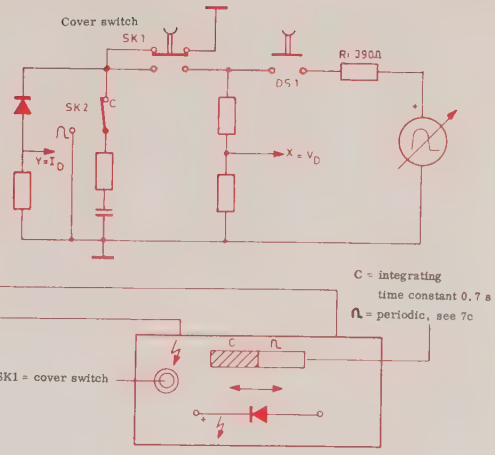


Fig. 41

Adapter PM 6546

Diode breakdown voltage
Measuring range 10 nA - 10 µA
with adapter PM 6546 and C
switched in.



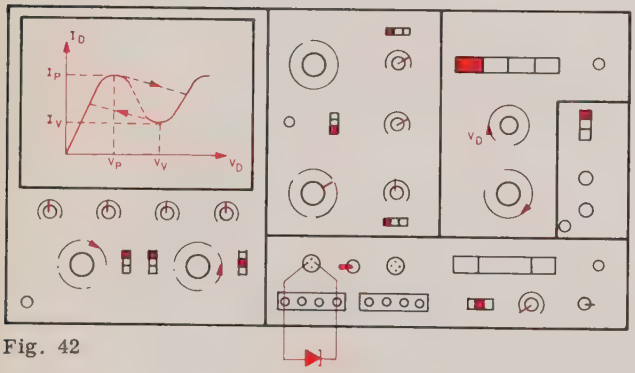
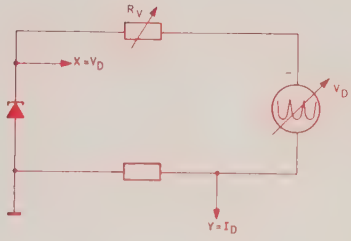


Fig. 42

TUNNEL-DIODE
PNP



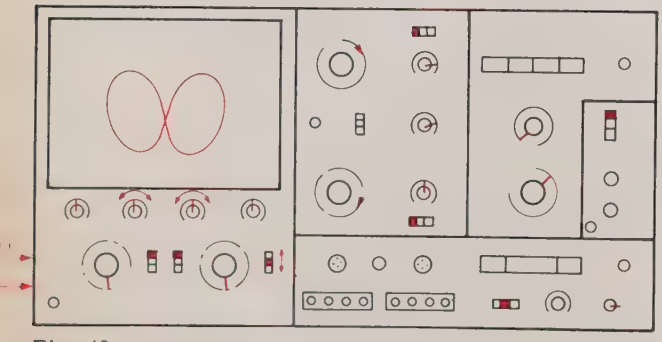
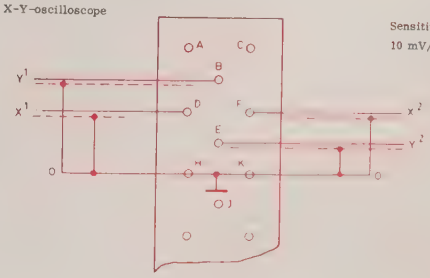


Fig. 43

PEM 3843

PEM 3843

External operation as
X-Y-oscilloscope



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10 mV/cm x and y

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